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Commentary

Reply to comment on "Appropriate experimental ecosystem warming methods by ecosystem, objective, and practicality" by Aronson and McNulty

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The letter by Amthor et al. (in this issue) on our paper (Aronson and McNulty, 2009) raised some interesting questions and noted an error in our original text. In Aronson and McNulty (2009), we misstated that anthropogenic-induced global warming would result from increased infrared radiation (IR), when the sentence should have read increased convection and conduction. The authors do not believe that increased greenhouse gas emissions will increase solar radiation output, or significantly increase IR to the Earth's surface. We thank Amthor et al. for that correction.

The assertion that IR lamps mimic the action of global warming due to increased longwave radiation on the land surface was cited from Harte et al. (1995). However there have been advances in the study of global warming heat transfer, which were not considered. This assertion was erroneously repeated in Aronson and McNulty (2009) and we thank Amthor et al. for this correction as well.

In our paper we made recommendations for ecosystem warming study methods based on the literature available on simulated ecosystem warming. Of the active warming methods in the literature, only two have been published on extensively, and therefore lend themselves to review: heat-resistance cables buried in or on the soil surface and IR lamps. Of these, only IR lamps transfer heat to the soil and air above the surface without direct contact of a heating element on the soil. Given that IR lamps do not contact the soil surface directly, and therefore minimize *in situ* disturbance, we stand by our assessment of these methods. However, any new technologies which can actively heat the soil and surrounding air effectively and better mimic the action by which global warming will warm the soil, would be welcomed by the scientific community.

Our discussion of passive nighttime warming is consistent with the current IPCC assessment, in that changes in downward longwave radiation affect nighttime or winter surface temperatures, as stated by Denman et al. (2007) "... the nighttime temperature change to be a result of increased nighttime cloudiness, and hence downward longwave radiation connected to the increase in aerosols [in the atmosphere]". As Amthor et al. state, this phenomenon is constrained to specific geographic (i.e. colder) regions. We asserted that study sites also need to have significant radiation input for this method to be viable. The combination of these factors may be why this method is most often used at the mid-latitudes (Aronson and McNulty, 2009). We did not advocate the expansion of this experimental practice, but rather that of chamber-based methods for passive warming experiments.

The notation by Amthor et al. on the effect of various warming methods on water vapor pressure differences (VPD) is indeed an important (and confounding) impact of ecosystem response to global warming. However, we could not locate a sufficient number of published studies that regulated (or adequately measured) relative humidity (RH) in conjunction with ecosystem warming to evaluate the practicality of alternative warming methods on regulating RH. While we agree with Amthor et al. that some forms of ecosystem warming should lend themselves more easily to the manipulation of RH in conjunction with warming, there was little data to support the practical application of this theory at the time our article was written. Given that data was lacking to assess the relative effectiveness of various passive or active warming treatments, it was not possible to factor RH into an overall assessment of warming method applicability. We agree with Amthor et al. that this issue deserves attention in future warming experiments.

Although some forms of active warming (e.g. active chambers) may well be conceptually or scientifically more robust methods for ecosystem warming studies as stated by Amthor et al., the most extreme warming is predicted to occur in the far northern latitudes, where less economic development limits the distribution of electrical power with which to perform active warming. There is also a deficit of experimental warming research in tropical regions, due to similar concerns. It would not be advantageous to the overall study of climate change impacts to only focus on those areas of the planet with sufficient infrastructure to permit active warming experiments. In recognition of

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resource limitations Aronson and McNulty (2009) emphasized the need for the recommendation of both an active *and a passive* approach to experimental warming depending on resource (i.e. funding and technological) availability, study objective, and geographic location. While we do not disagree with Amthor et al. regarding the conceptual superiority of active versus passive warming, the application of active warming is not feasible for all ecosystems of interest, and thus passive warming methods represent a practical option for many under-represented geographic locations. For these reasons, we stand by the conclusions presented in Aronson and McNulty (2009) regarding the most appropriate and practical application of soil warming experimental methods.

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